Emission Spectra of LSO and LYSO Crystal Scintillators Excited by UV Light, X-ray and γ-ray

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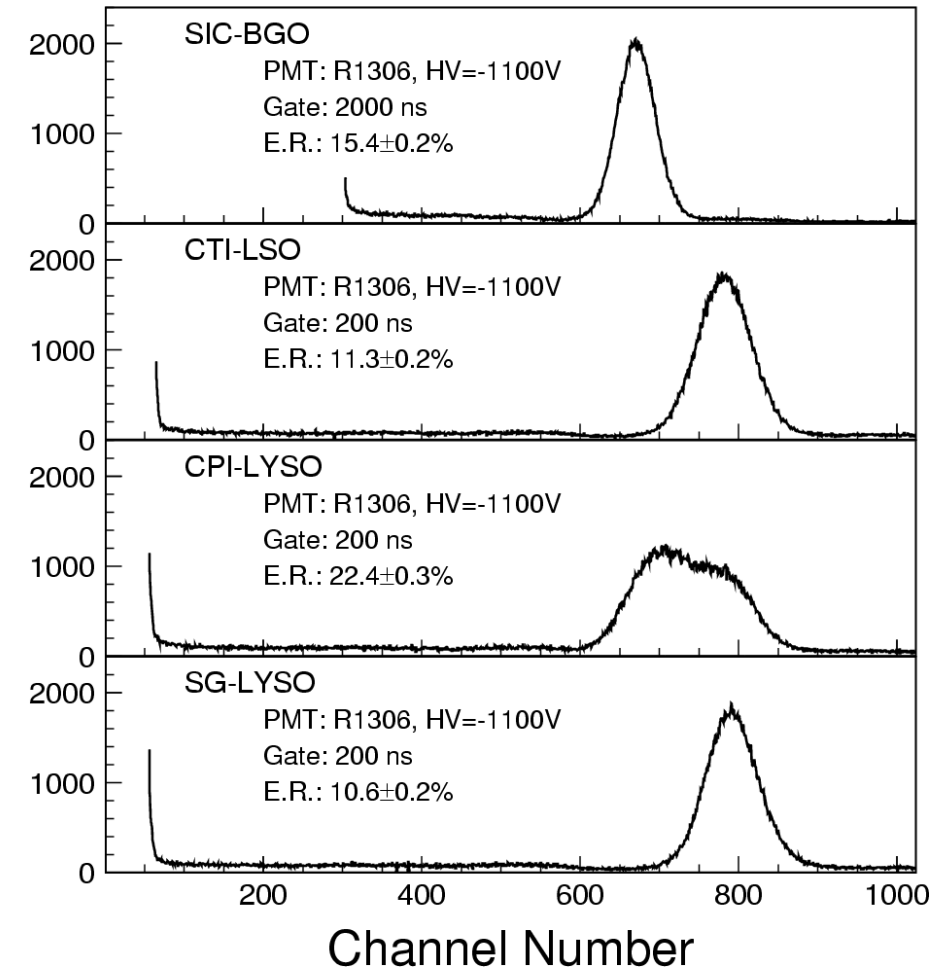
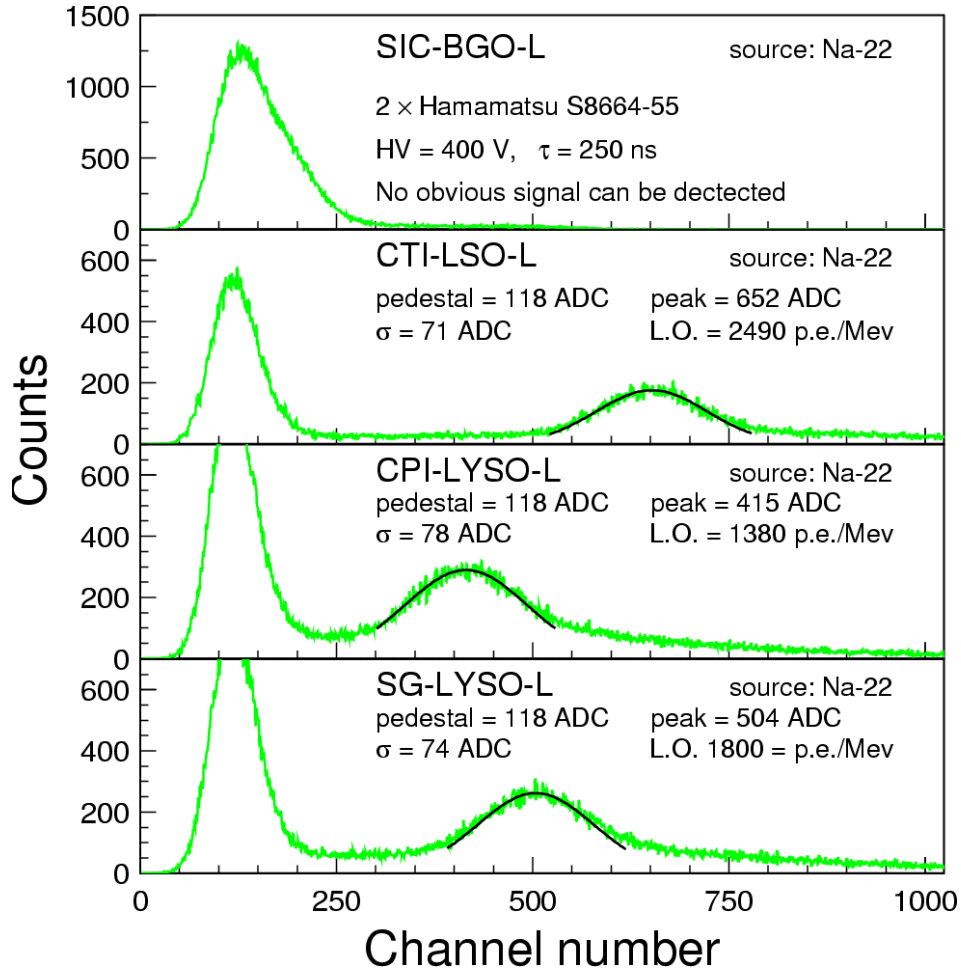
Introduction

We reported at Puerto Rico (NSS05, N12-6) a comparison of light output of large size (2.5 x 2.5 x 20 cm) LSO and LYSO samples, and found that a CTI LSO has a higher light output with APD readout, but not with PMT readout. This anomaly disappeared after γ-ray irradiation to 1 Mrad.



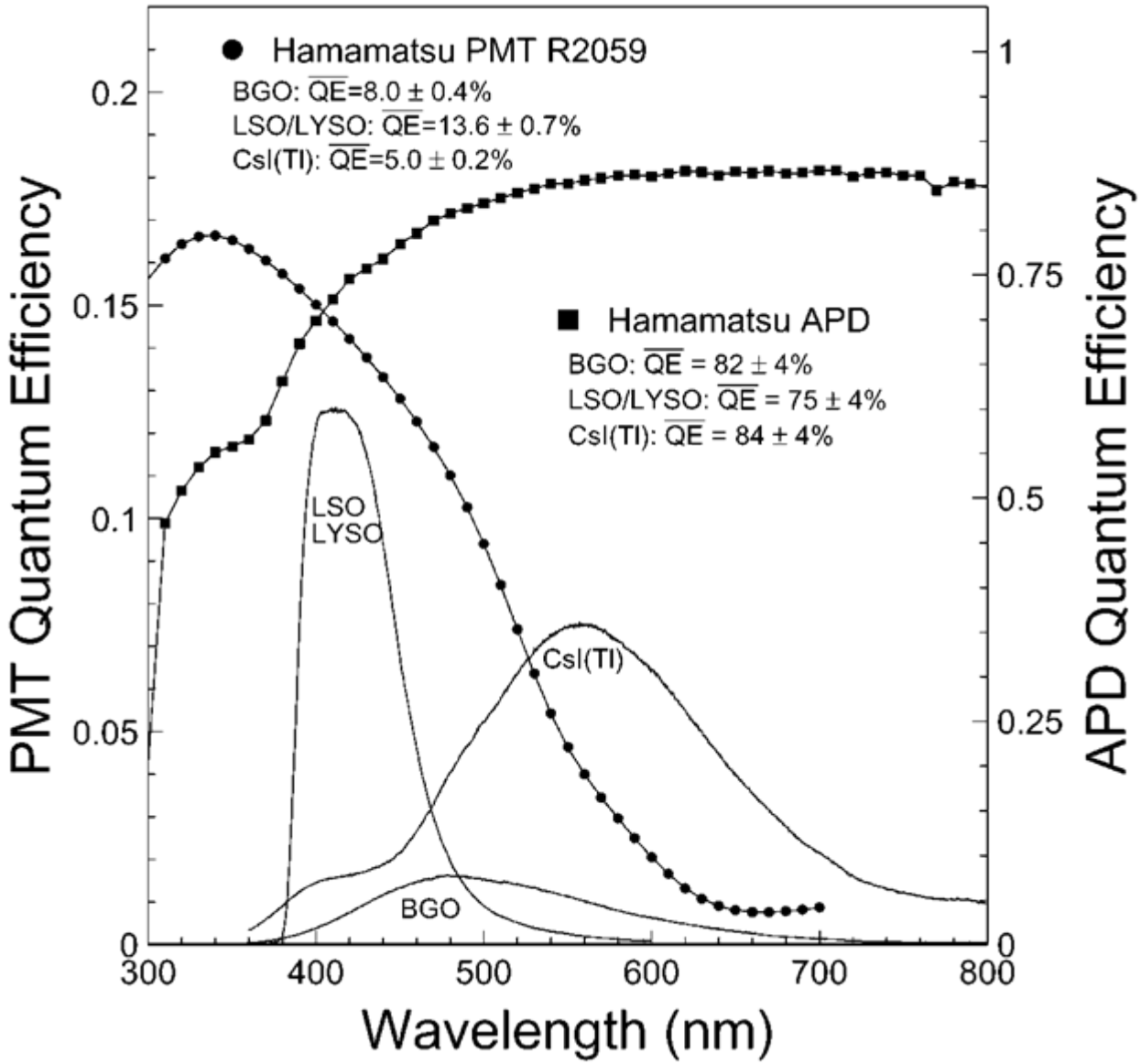


Quantum efficiency and Emission

Why?

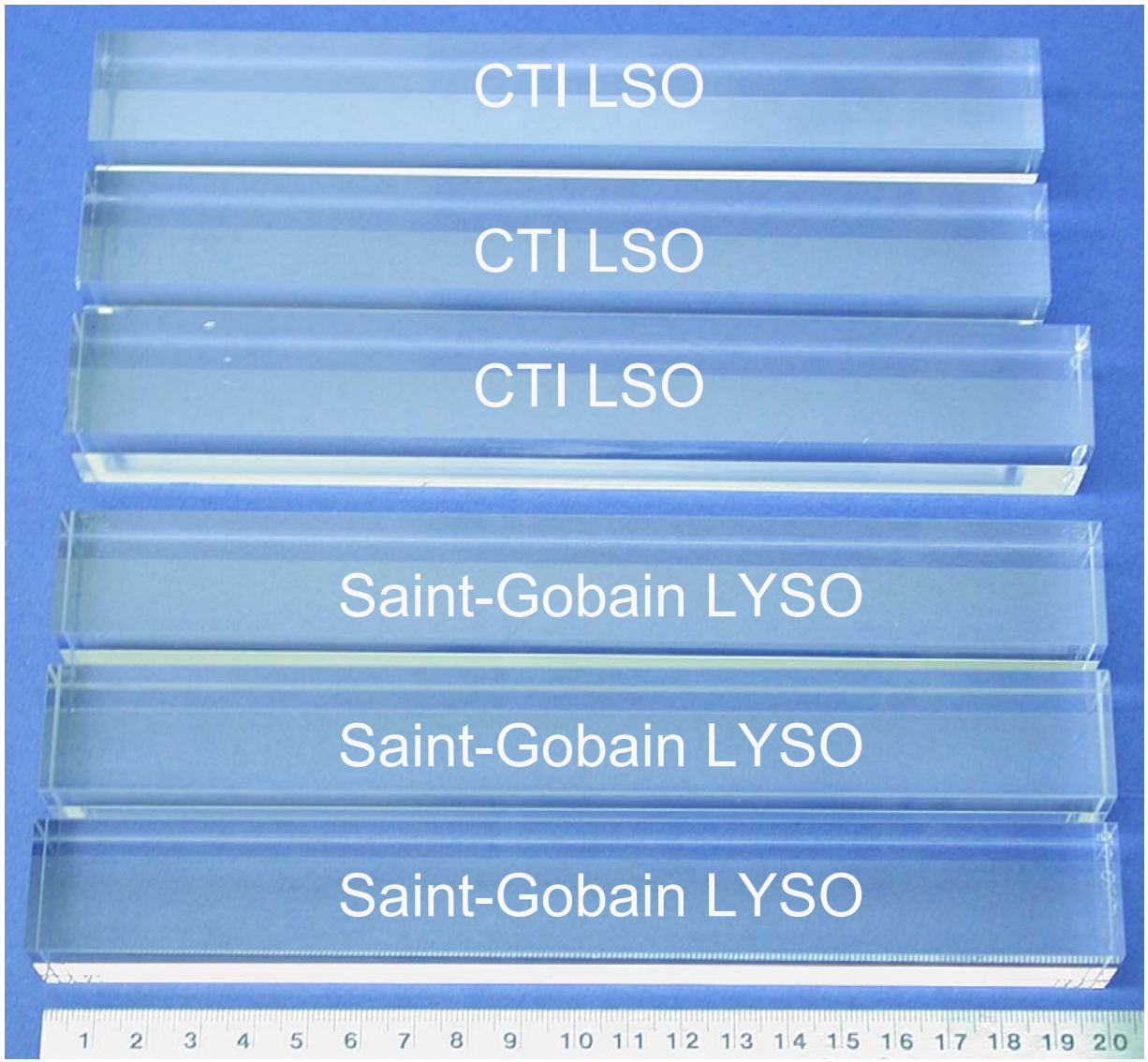
The LSO sample had an emission peaked at longer wavelength under γ-ray excitation, and the emission was changed after γ-ray irradiations.

Can we prove it?



Six Large LSO and LYSO Samples

2.5 x 2.5 x 20 cm (18 X_0) Bar

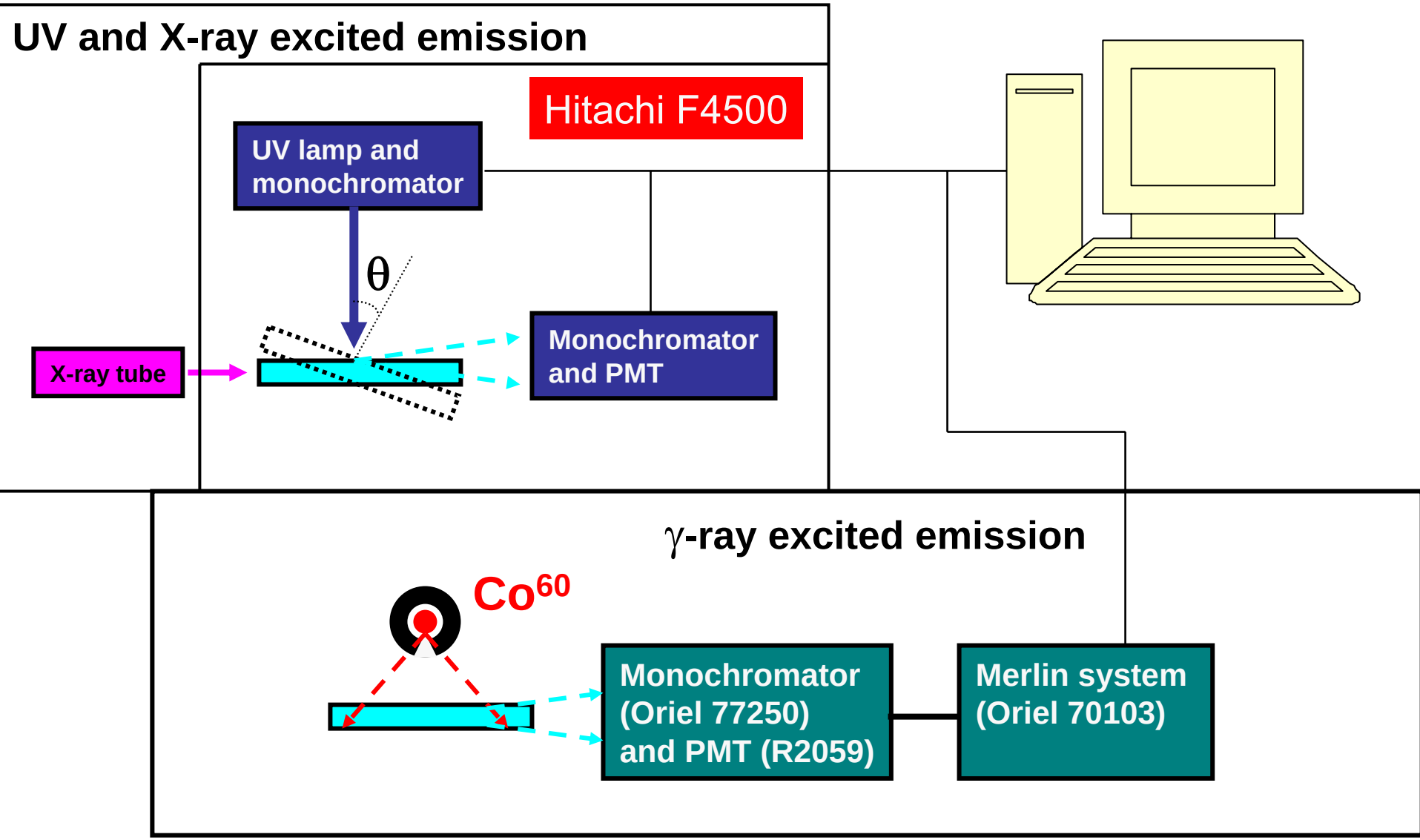


Three CTI LSO samples are provided by Chuck Melcher.

Three LYSO samples are purchased from Saint-Gobain.

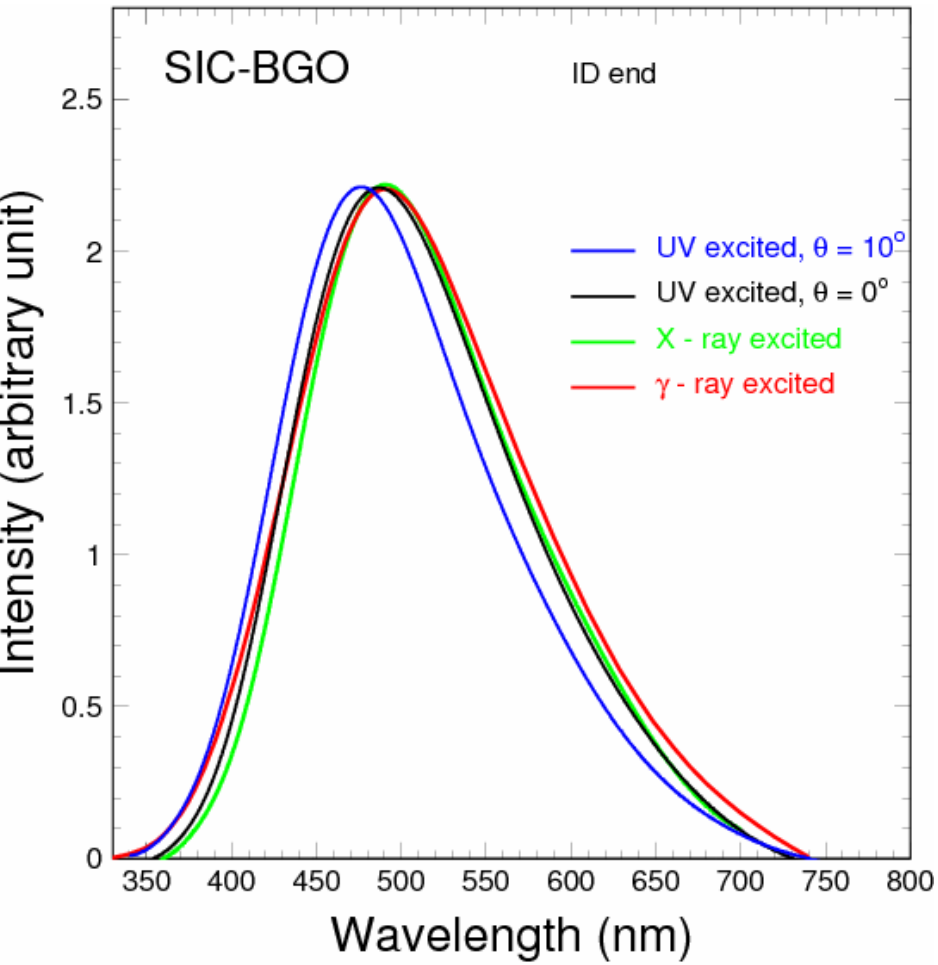
UV, X-ray & γ-ray Excited Emission

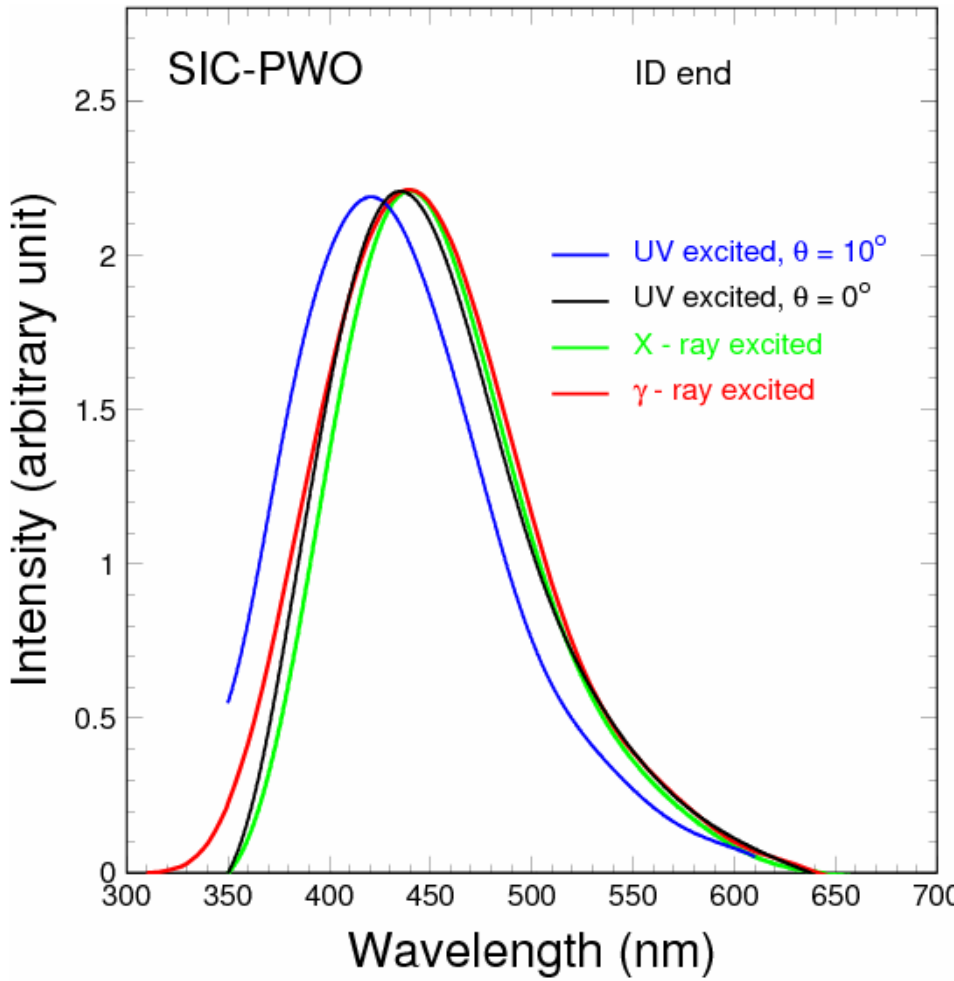
Photo-luminescence measured with θ = 10°: No internal absorption



System Checks

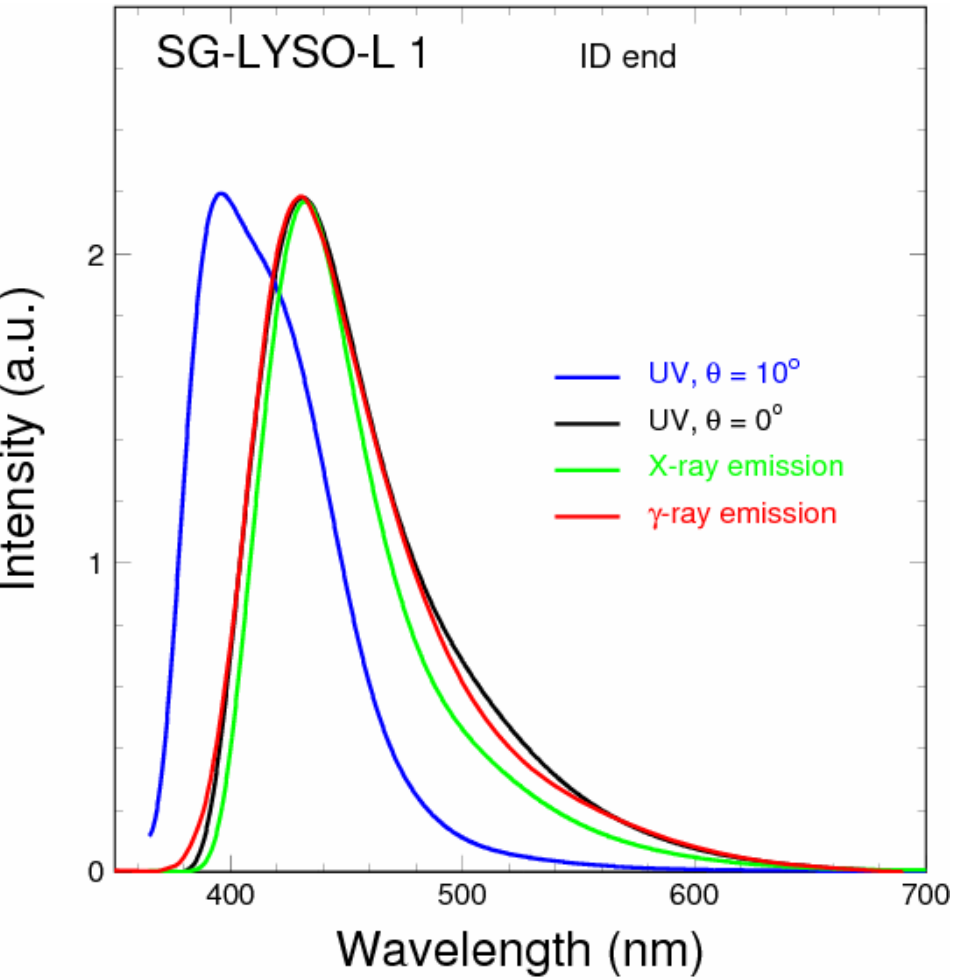
UV (θ=0°), X-ray and γ-ray excited emission spectra are consistent
UV (θ=10°) excited emission has a blue shift because of no absorption

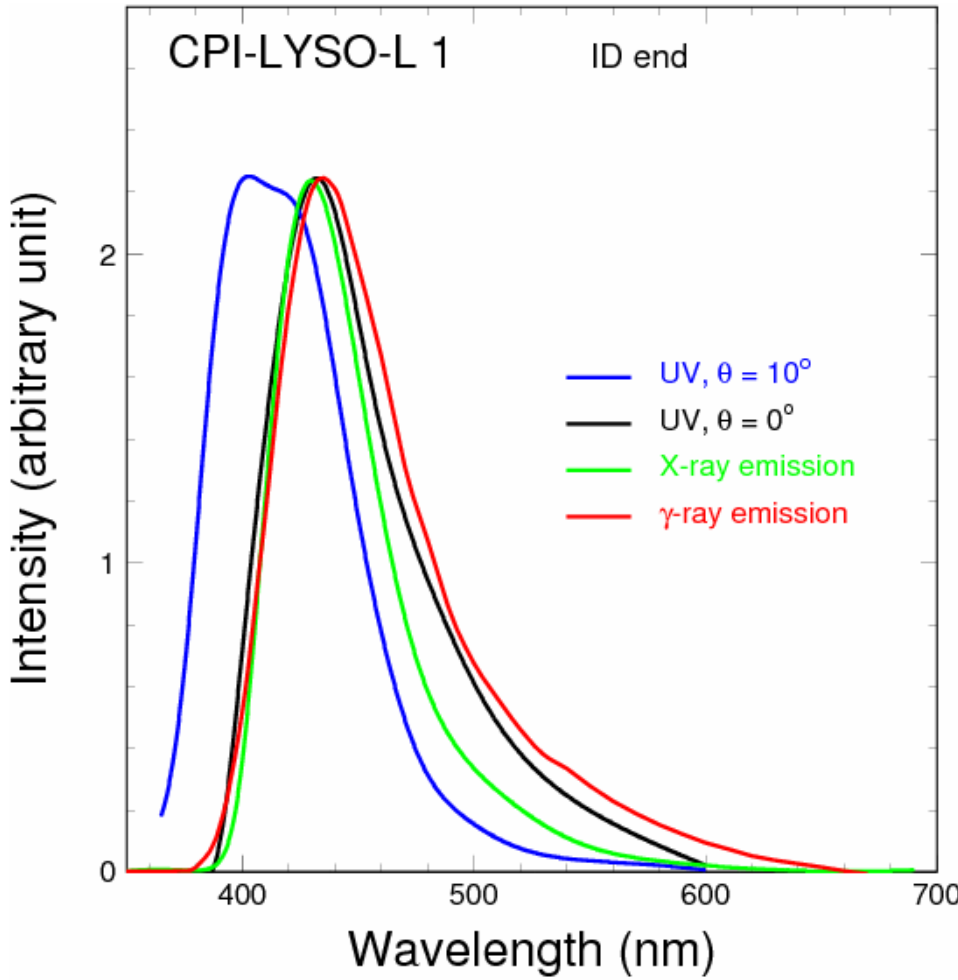




LYSO Emission

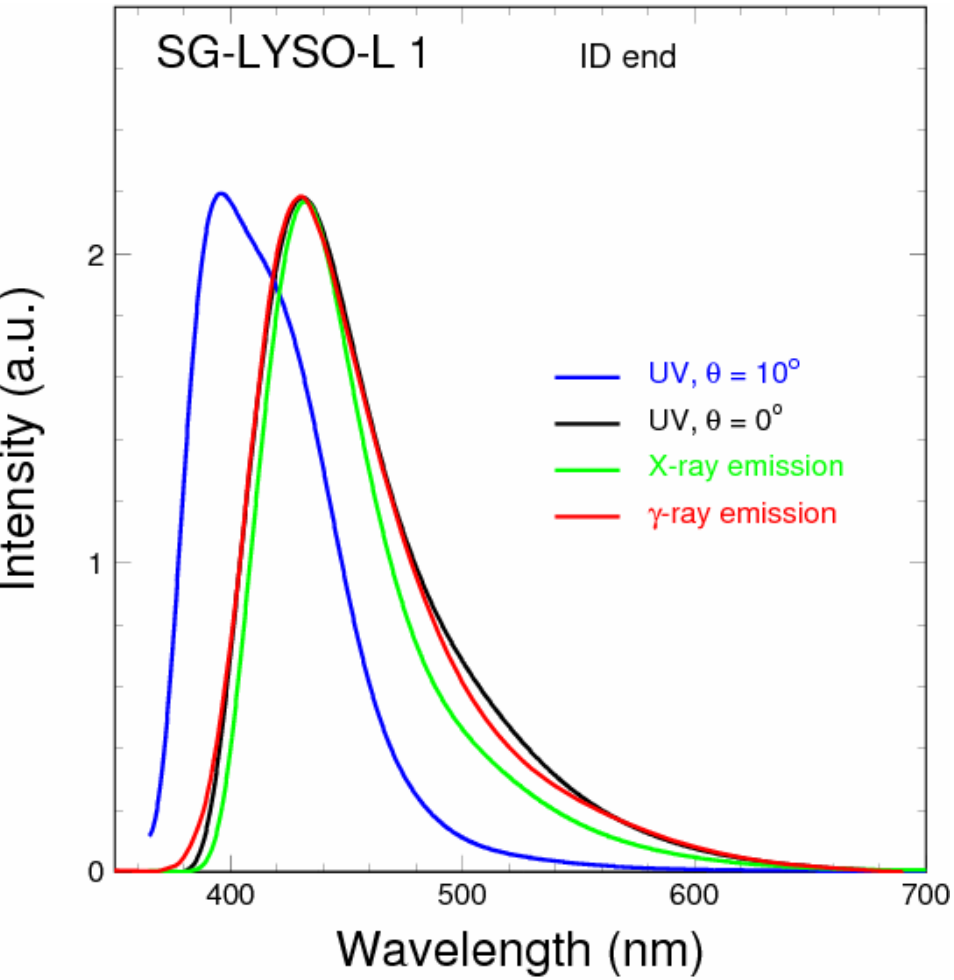
UV (θ=0°) and γ-ray excited emission spectra are consistent
UV (θ=10°) excited emission has a strong blue shift (See N49-1)
X-ray excited emission is slightly narrow. Why?





X-ray Excited Emission Narrow

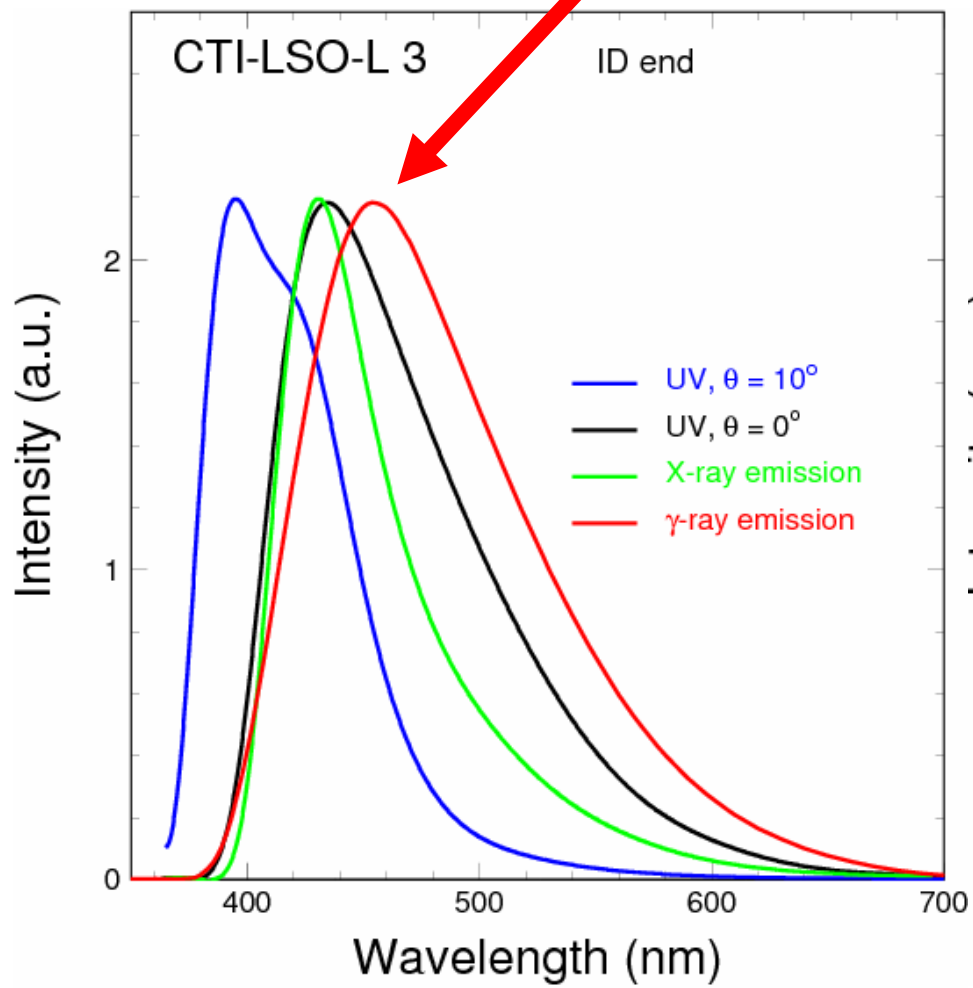
The narrow X-ray excited emission spectra of LYSO may be explained by a surface effect since X-ray does not penetrate.

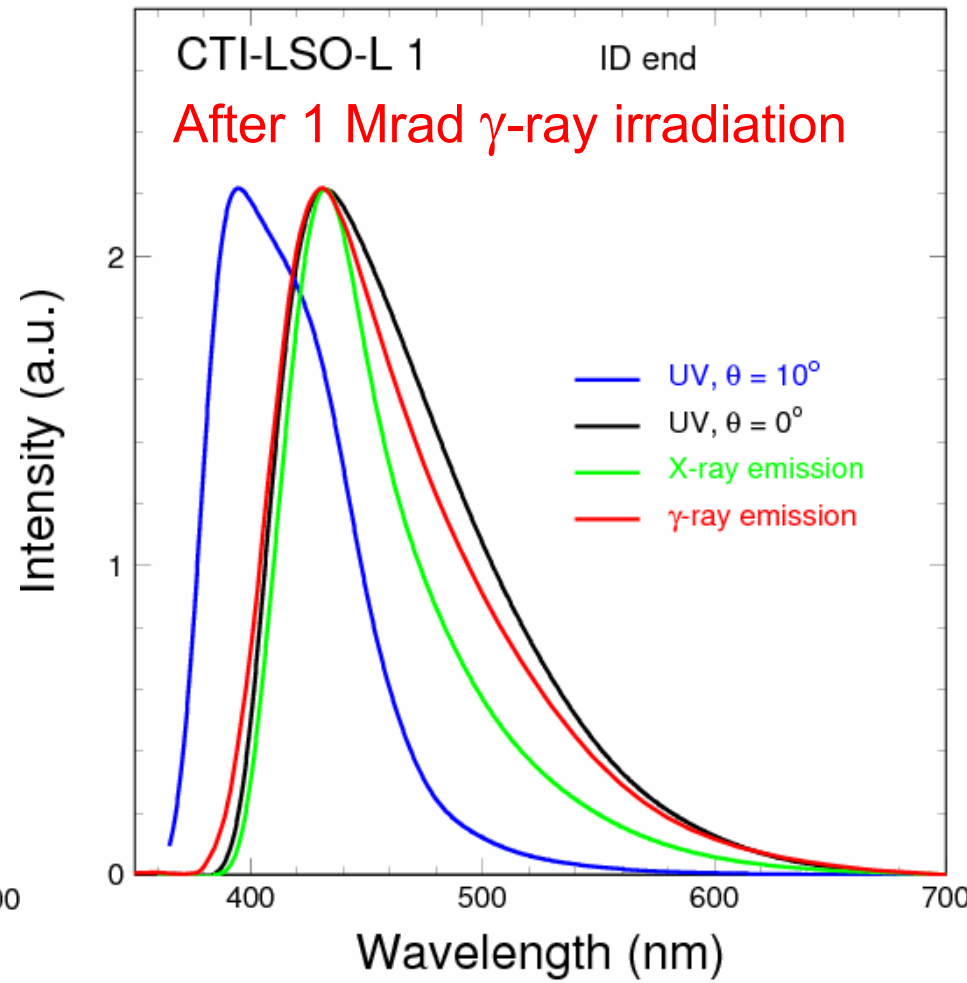


UV excitation (3-6 eV)	Attenuation length 100~700 μm
X-ray (8-30 keV)	Attenuation length ~10 μm
γ-ray (Co^{60}) (~1.2 MeV)	Radiation length 1.14 cm

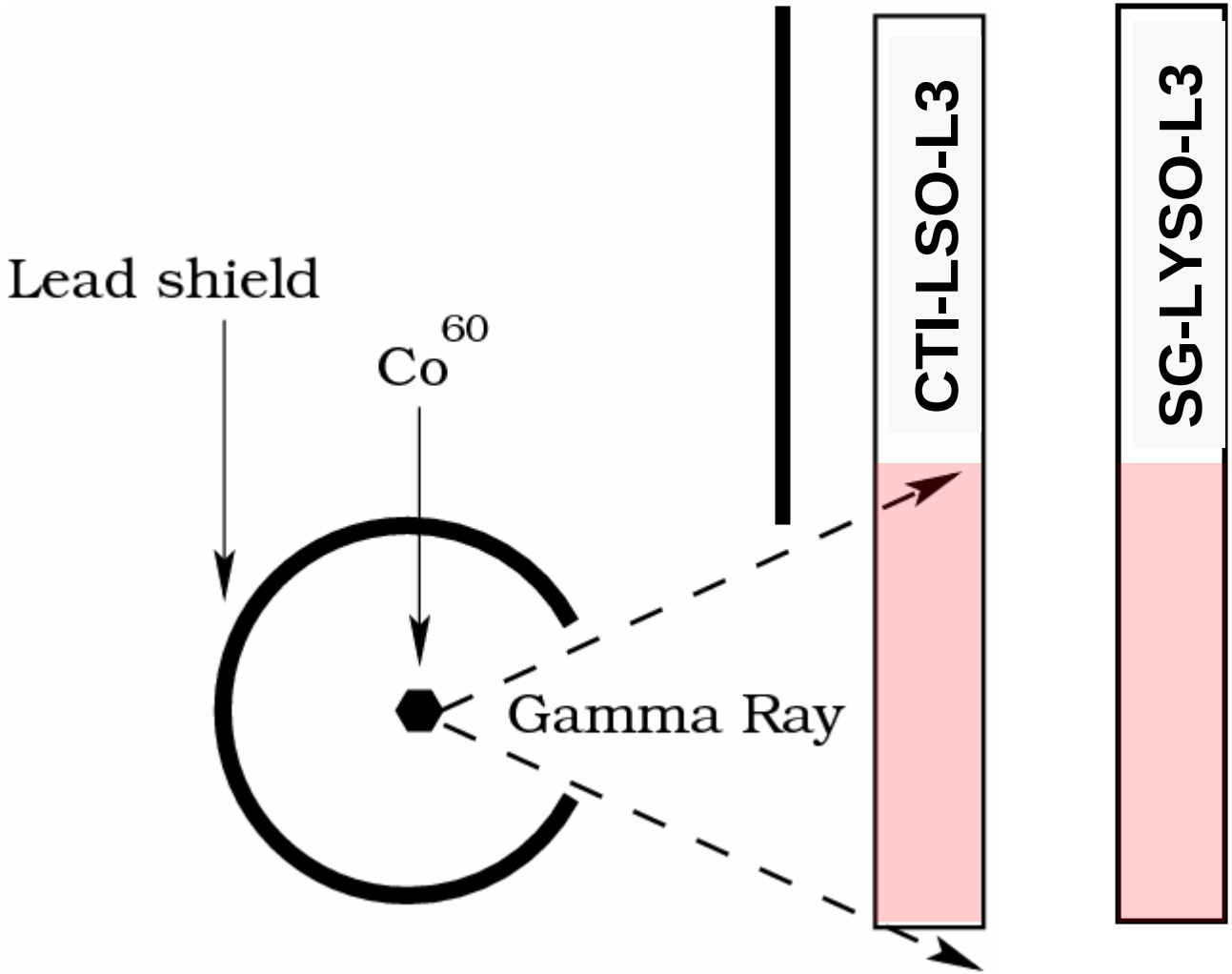
LSO Emission

All emission spectra are similar to that of LYSO, except that γ-ray excited emission has a "red shift", which disappeared after irradiations with γ-ray.





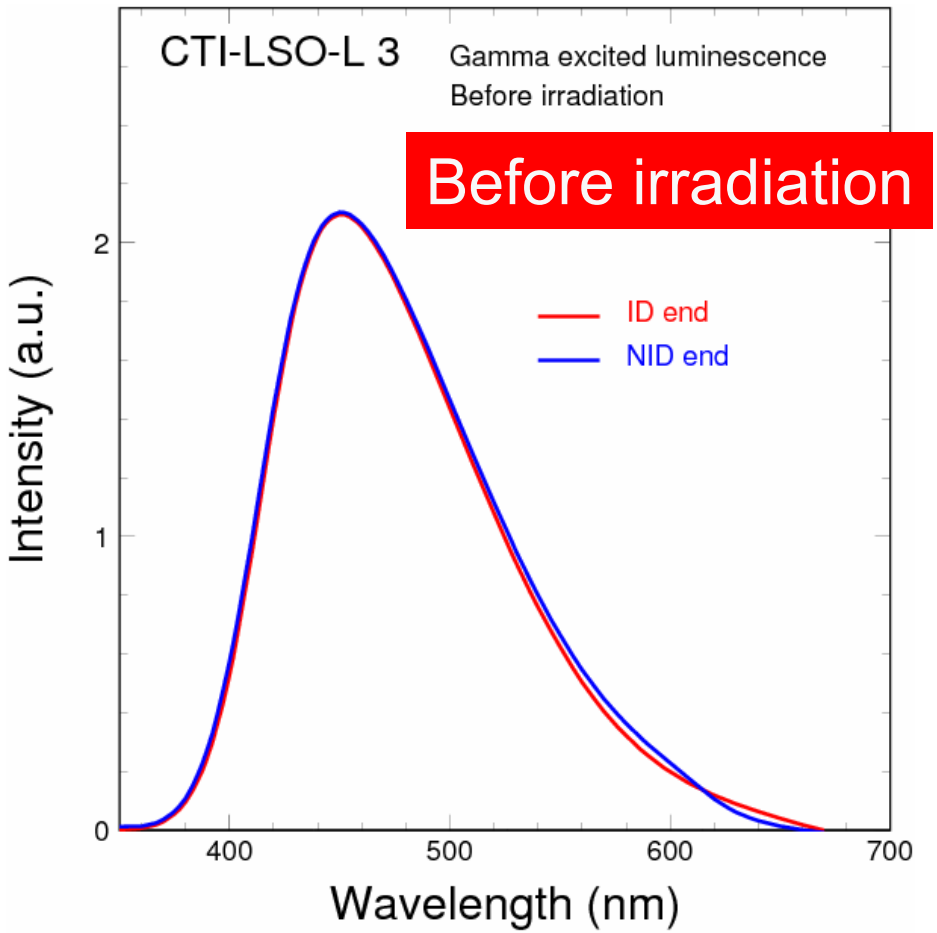
γ-Ray Irradiation on Sample's ID End

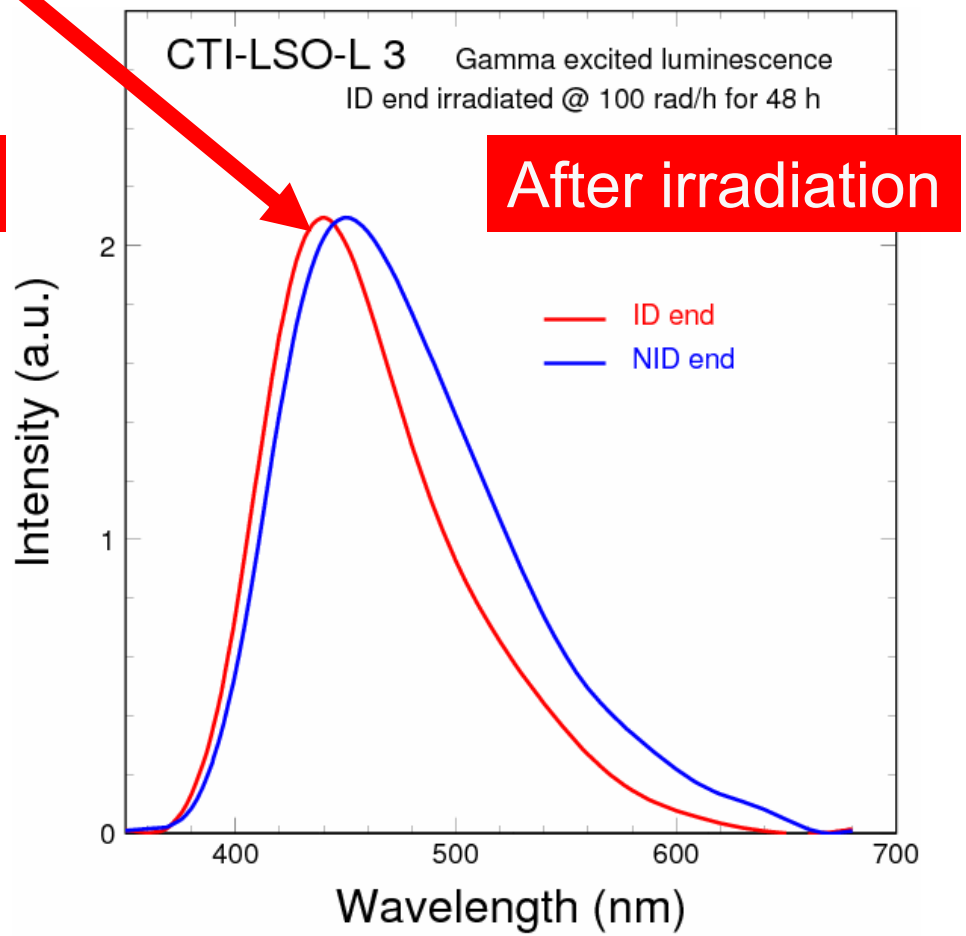


ID End received
~5000 rad

LSO: γ -Ray Excited Emission Spectra

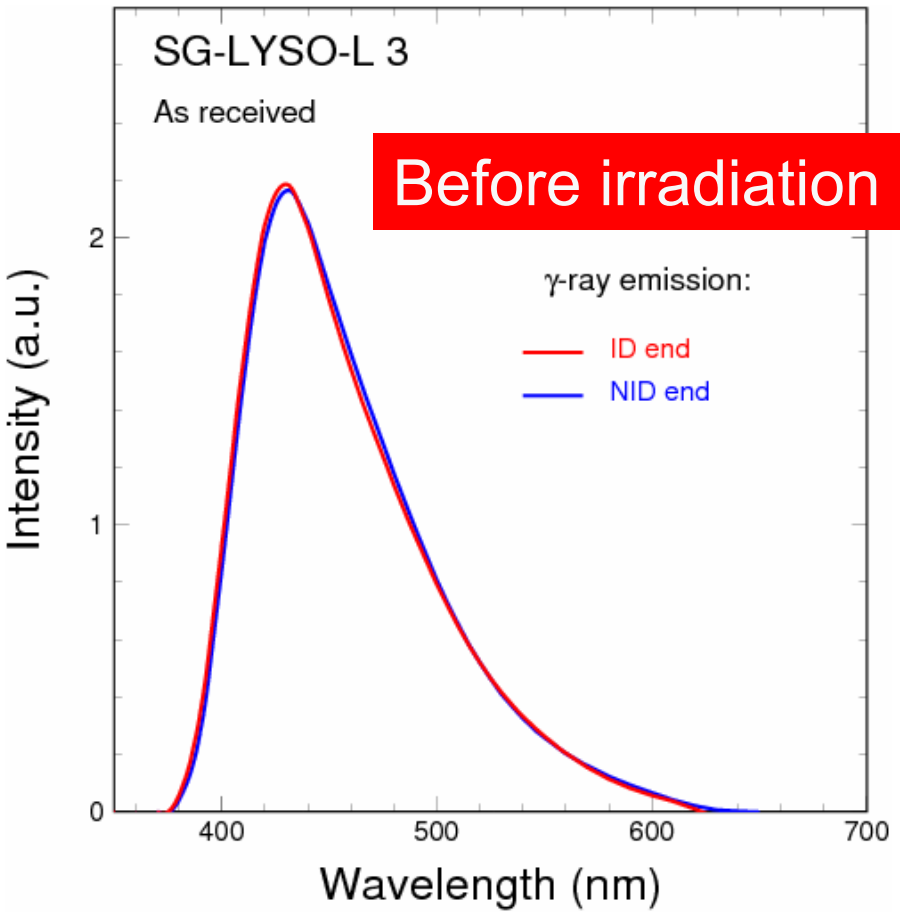
The emission peak of sample's irradiated ID end has a ~15 nm "blue" shift

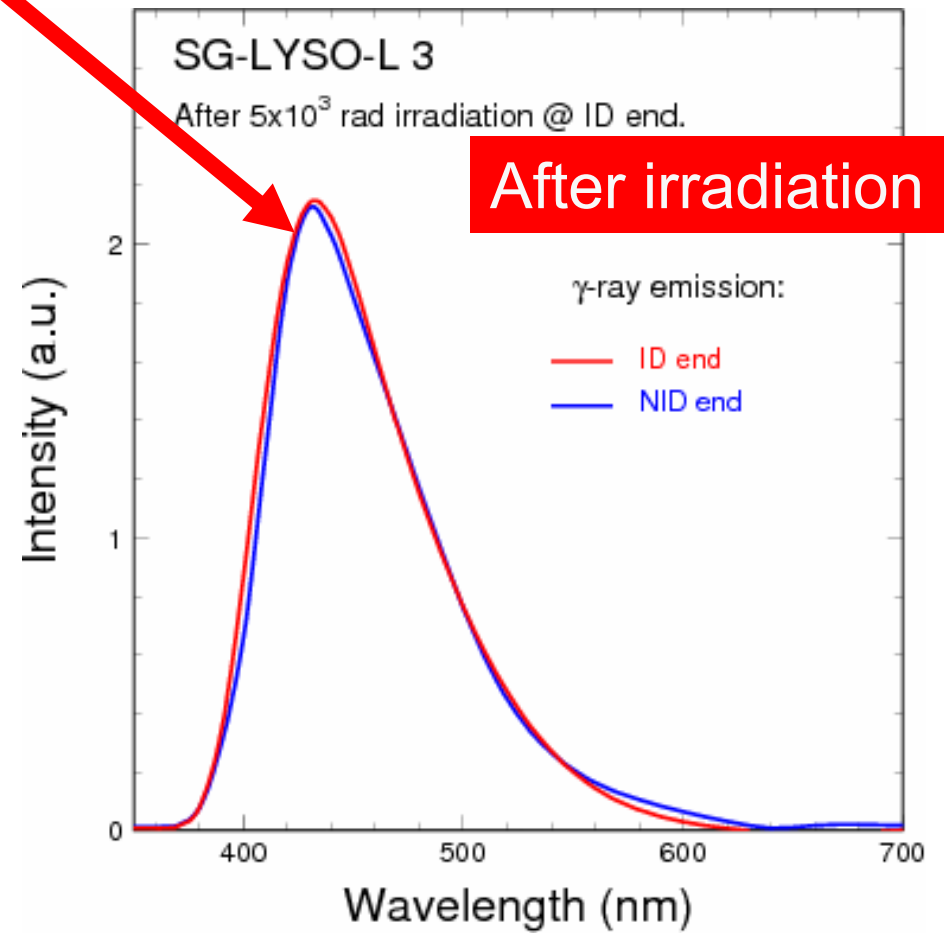




LYSO: γ -Ray Excited Emission Spectra

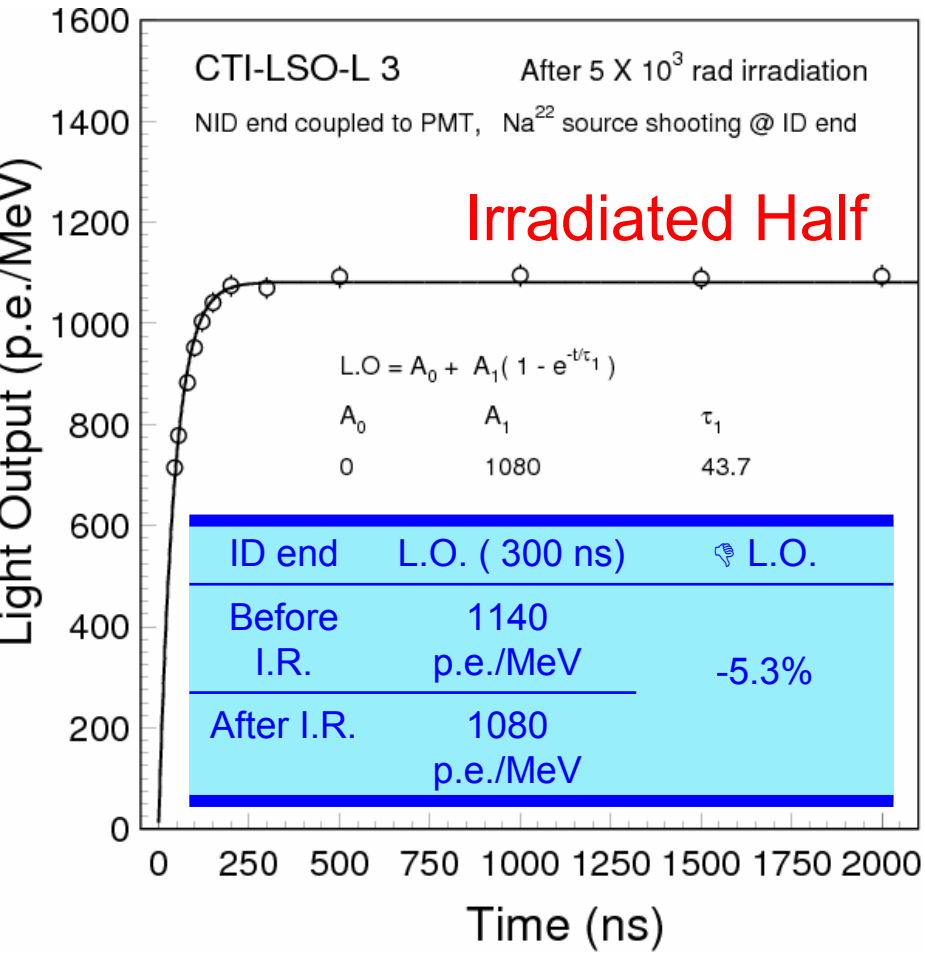
The emission peak of sample's ID (irradiated) end has NO "blue" shift

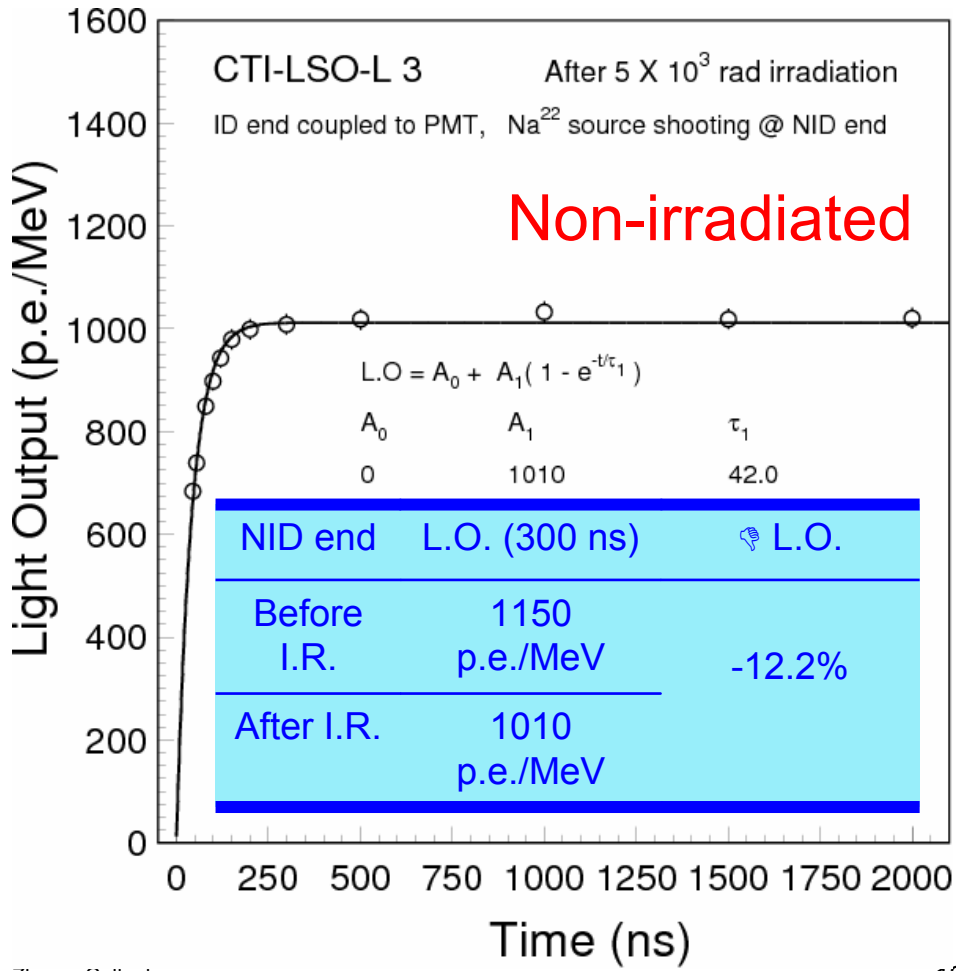




LSO Decay Time and Light Output

The irradiated end (ID) has no change in decay time. Its light output degradation is half of that of the NID end because of the emission "blue shift".

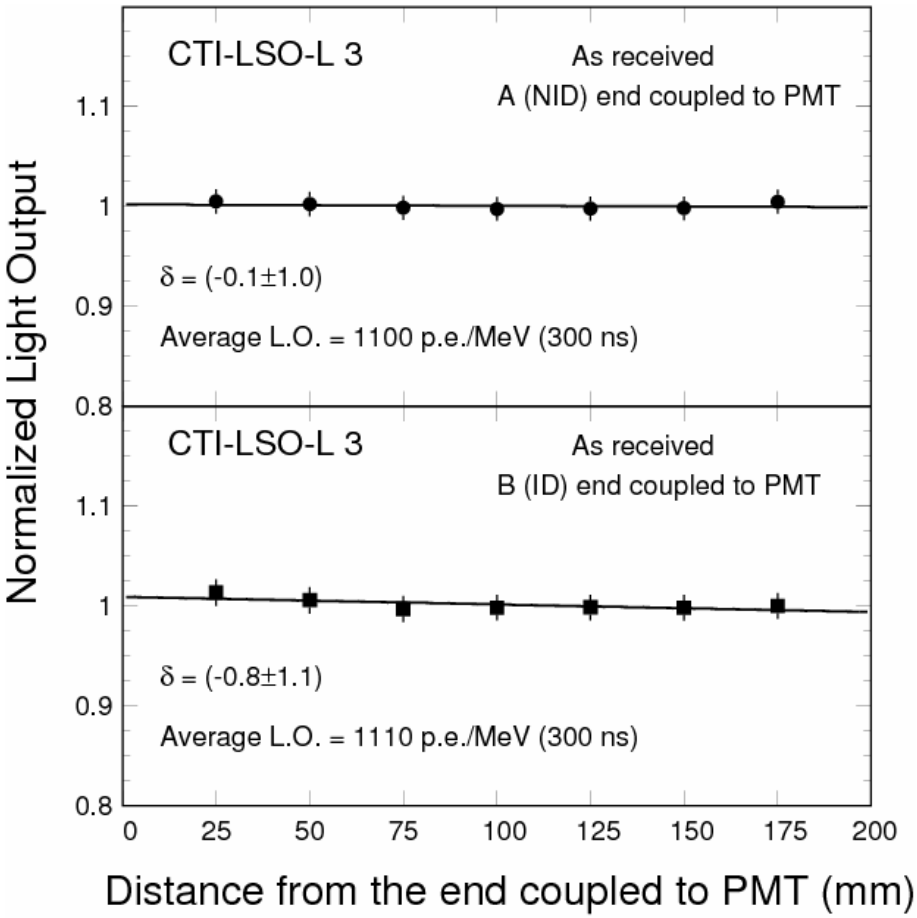




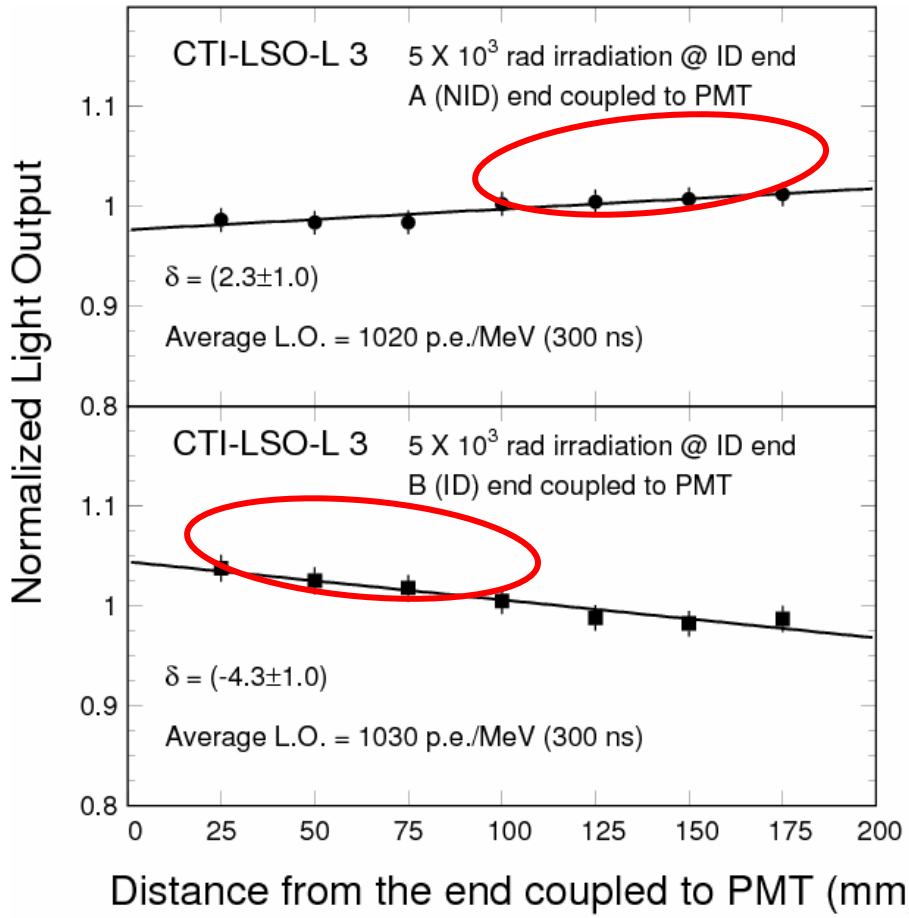
LSO Uniformity with PMT Readout

The emission "blue shift" of the irradiated end causes a relative larger LO for the PMT readout.

Before irradiation



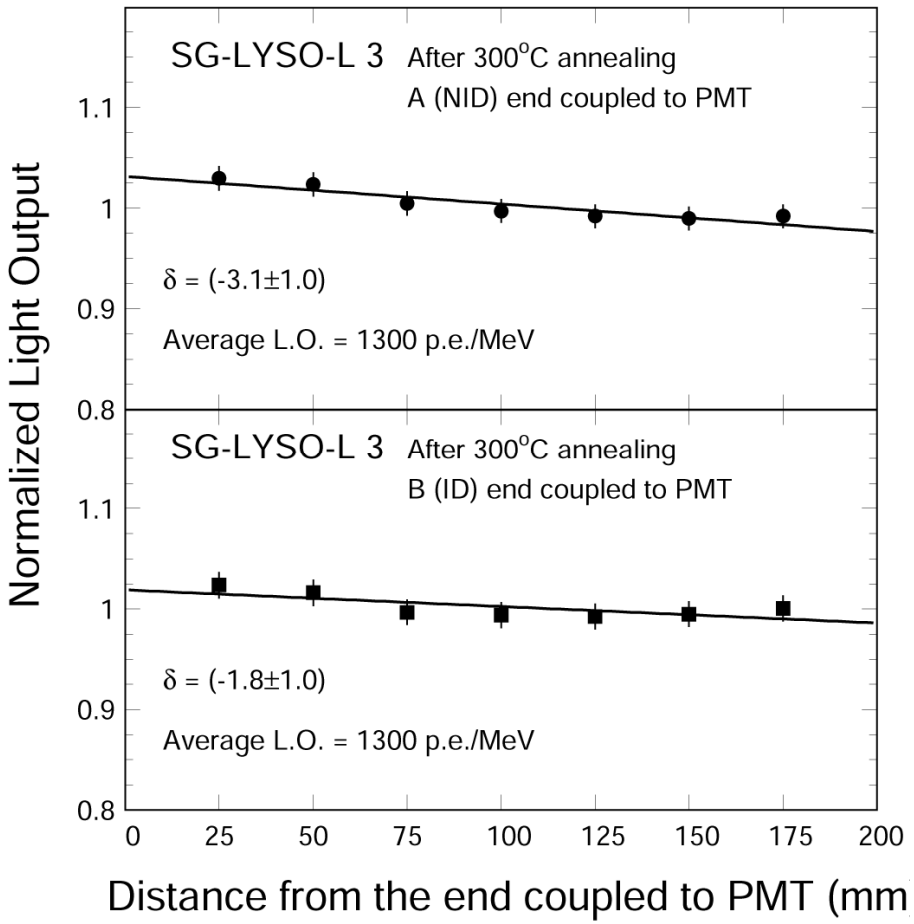
After irradiation



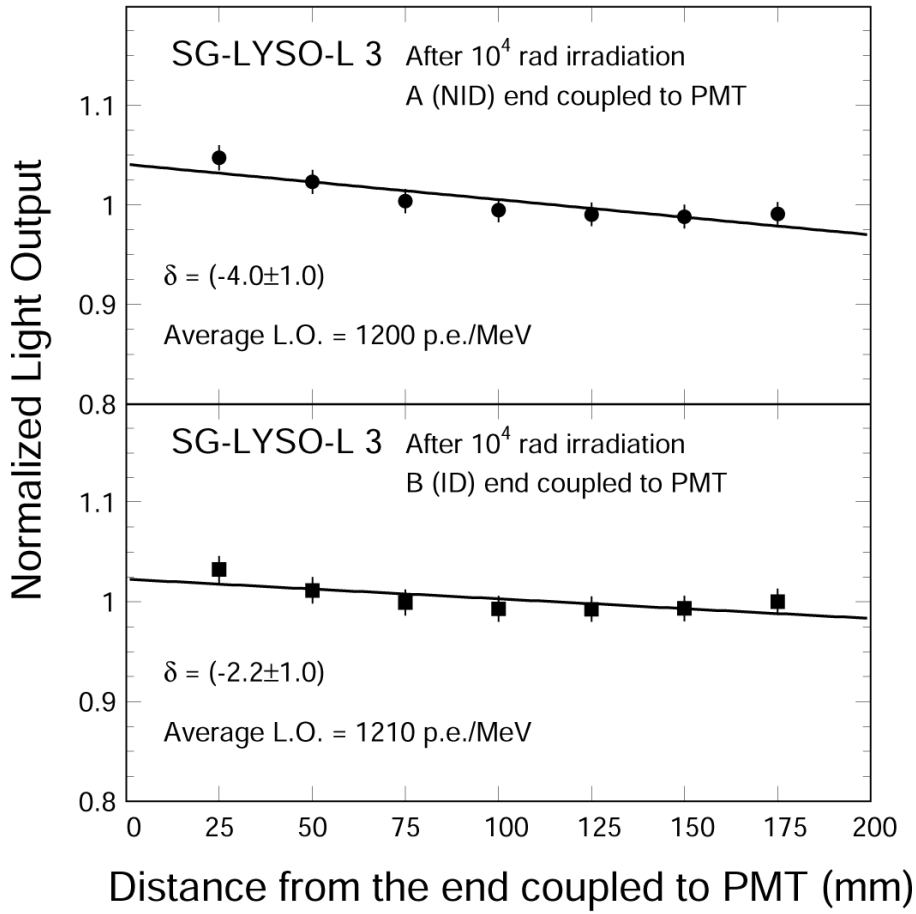
LYSO Uniformity with PMT Readout

No significant variations in the light output and light response uniformity for the PMT readout

Before irradiation

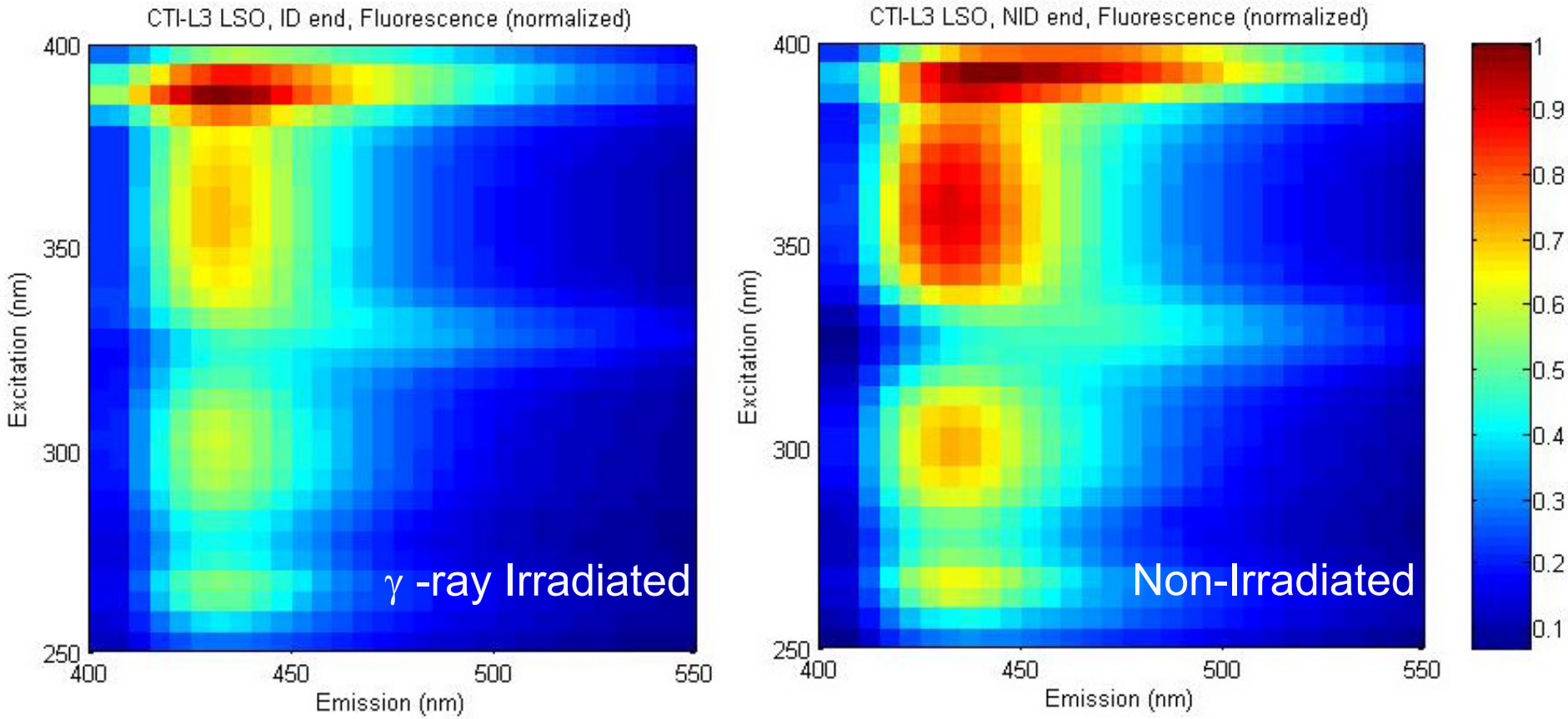


After irradiation



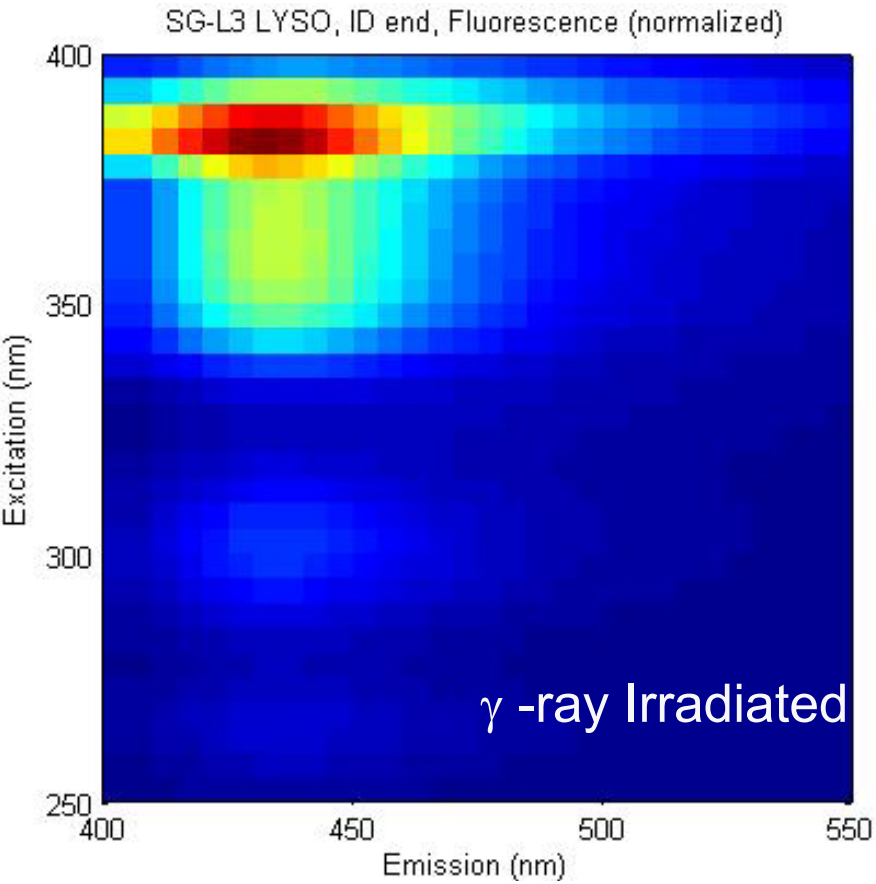
UV Excited Emission Spectra of Two Halves of the LSO Sample

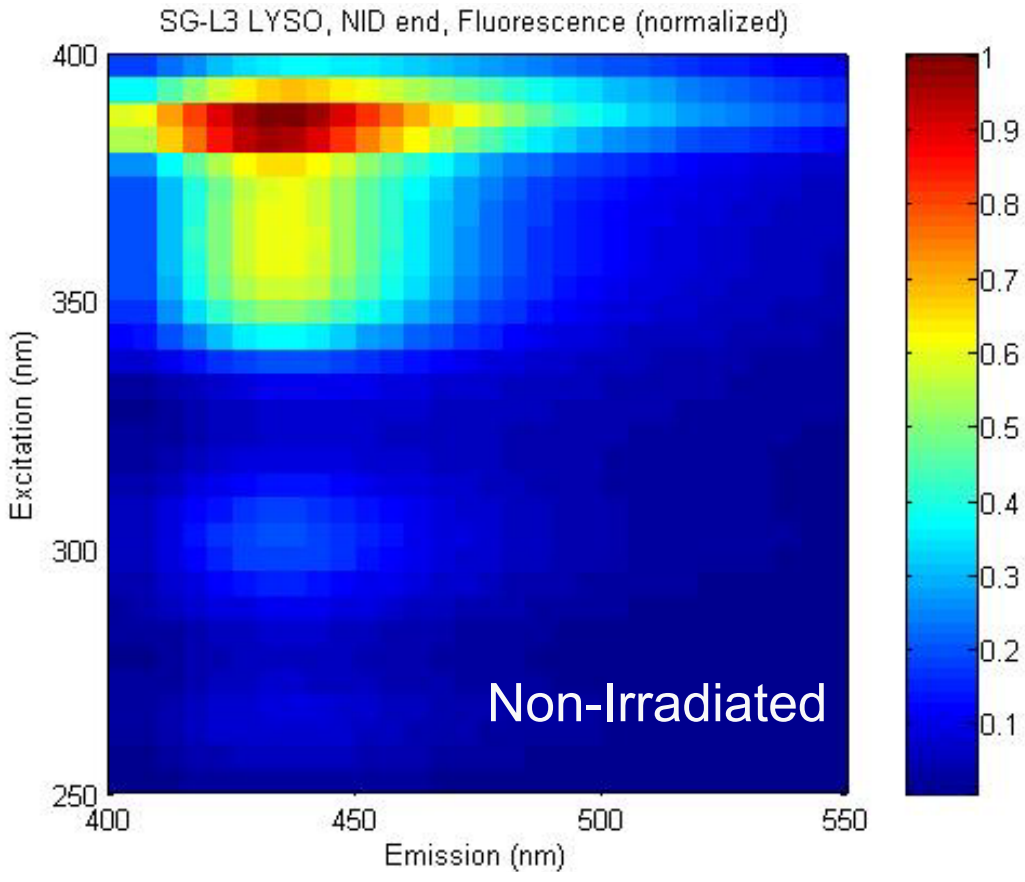
The γ -ray irradiated half shows less long wavelength emission when excited at 325 nm and 380 nm.



UV Excited Emission Spectra of Two Halves of the LYSO Sample

The γ -ray irradiated half shows consistent emission as the non irradiated half when excited at 325 nm and 380 nm.

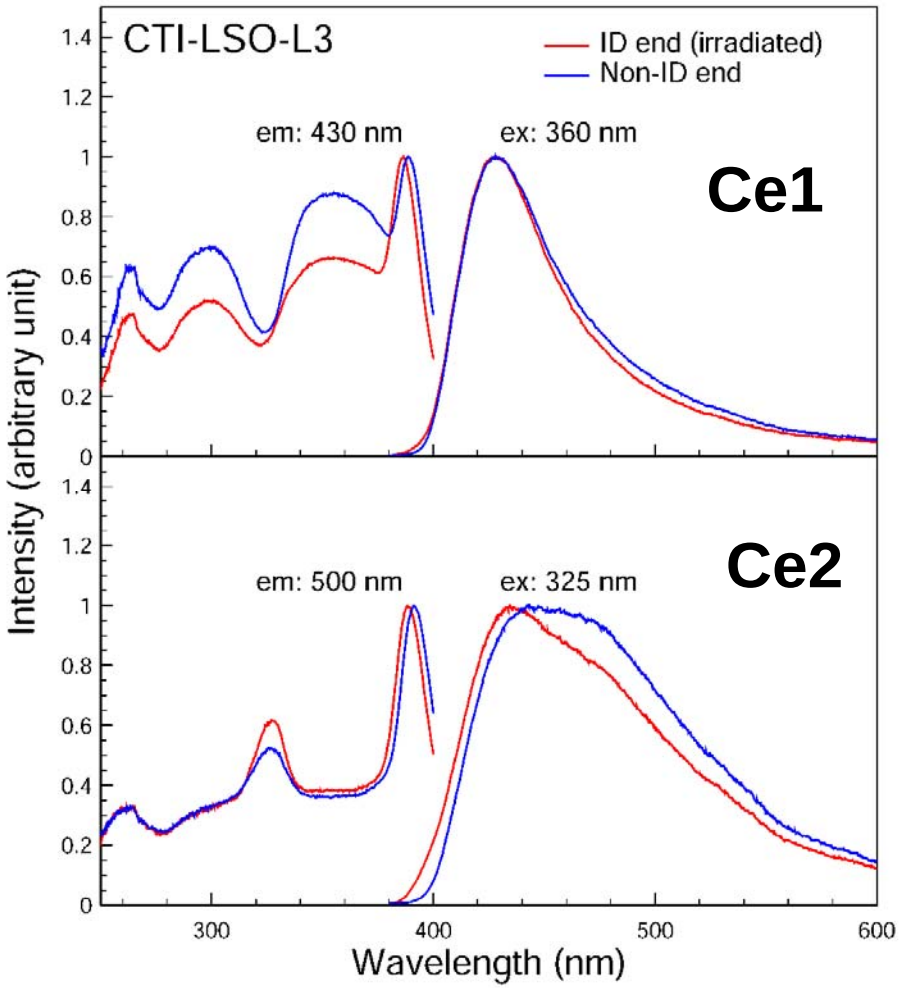


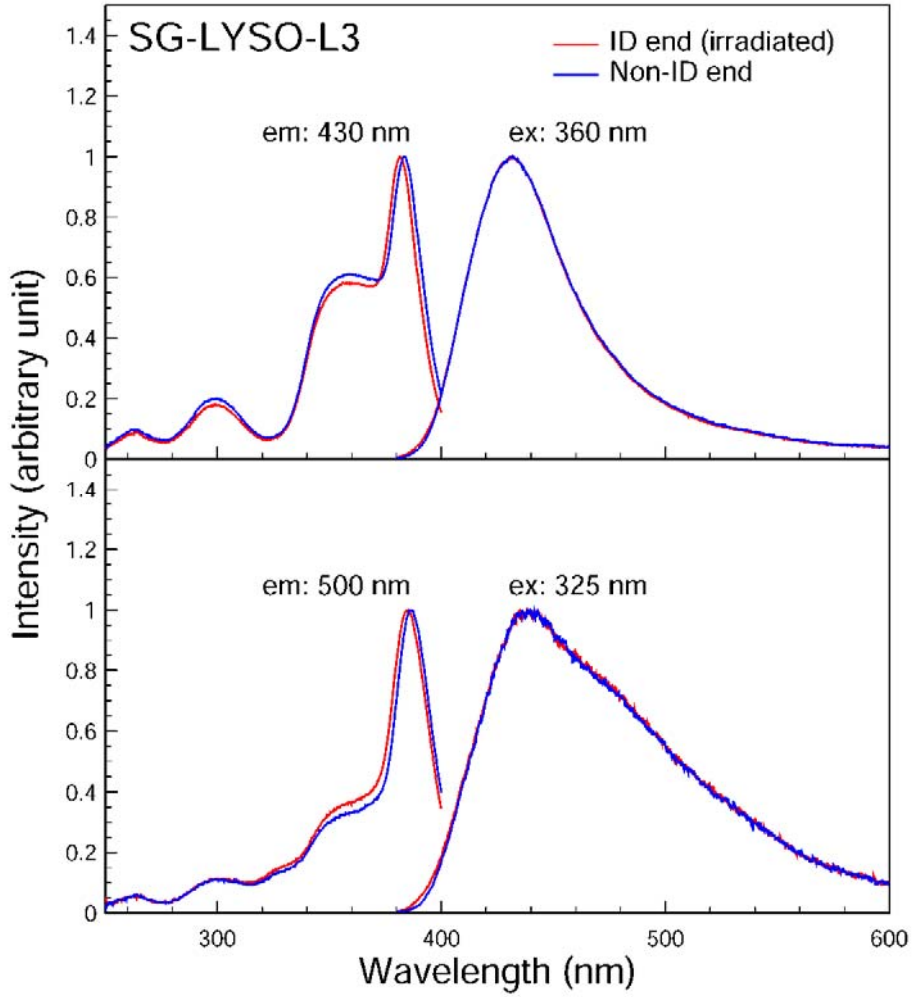


Ce^{3+} Luminescence Centers in LSO

J.D. Naud et. al., IEEE Trans. Nuclear Sci., Vol.43, p1324, June 1996

Ce1: two regular Lu^{3+} crystallographic sites, ex: 360 nm, em: 430 nm
Ce2: irregular sites, proposed “interstitial site”, ex: 325 nm, em: 500 nm





Conclusions

- A strong blue shift of the photo luminescence (θ=10^o) in LSO/LYSO is attributed to its self absorption.
- A narrow X-ray excited emission spectra in LSO/LYSO seems caused by a surface effect
- A broader γ-ray excited emission spectrum with a "red shift" as compared to the X-ray and UV excited emission spectra is observed in large size LSO samples. This shift disappeared after γ-ray irradiations. This observation consists with the light output and uniformity data and with what reported in NSS05 at Puerto Rico.
- No such shift was observed in large size LYSO samples.
- We tentatively attribute this shift to the contribution of the "irregular" sites of Ce^{3+} (the component around 450 nm). The fact that it can be "cured" more or less by γ-ray irradiations supports that this site is a defect perturbed irregular site of Ce^{3+}.